Integrated Power Generation with a Spark Ignition Engine Fueled with Pyrolysis Gas

M. Ratcliff*, C. Baca-Overly, S. Deutch, C. Feik, J. Graham and S. Phillips
National Renewable Energy Laboratory, 1617 Cole Blvd, Golden, Colorado, USA 80401
Fax: 303-384-6363; matthew_ratcliff@nrel.gov

A 4-cylinder, 4-stroke, spark ignition (SI) engine of 2.5L displacement and 9.4 compression ratio, has been operated for over 100 hours on wood-derived pyrolysis gas to measure exhaust emissions and performance characteristics. The pyrolysis gas was produced in NREL's Thermochemical Process Development Unit (TCPDU) using a two-step, indirect gasification process as described in a companion paper [1]. A typical fuel composition (not including light "tars" that escape the wet scrubber) is shown in Table 1.

Table 1. Pyrolysis Gas Composition from TCPDU

H_2	CO	CH_4	C_2H_4	C_2H_2	C_2H_6	CO_2	N_2	H_2/CO
17.9 %	34.9 %	15.8 %	4.7 %	1.0 %	0.5 %	17.3 %	6.0 %	0.51

The engine-generator (genset) maximum output (manufacturer's rating) on natural gas was 17 kW. The genset also achieved 17 kW on pyrolysis gas, although with less stable performance. This is in contrast to spark ignition engines operating on producer gas, which typically must be derated 40-50% [2] (presumably compared to gasoline; otherwise unmodified SI engines are derated approximately 13 % when switching from gasoline to natural gas). At loads ? 14 kW, the genset's performance on pyrolysis gas was as good or better than natural gas, as measured by the ability to maintain 60 ± 0.3 Hz.

In order to reduce NOx emissions and increase fuel efficiency, the limits of lean burn operation were explored. The extended lean flammability limits of the hydrogen-rich pyrolysis gas allowed excess air operation out to ? = 1.5 (6.9 % exhaust oxygen) with stable performance (± 0.3 Hz) at loads up to 14 kW. For stable operation using natural gas, the maximum ? was 1.2 (3.8 % exhaust oxygen) at 14 kW. For both fuels, lighter loads allowed leaner operation. It is well known that lean burn operation has a dramatic effect on reducing NOx emissions from internal combustion engines [3]. This effect with the pyrolysis gas fuel is shown in Figure 1, along with carbon monoxide and total hydrocarbon emissions and efficiency. Although hydrocarbon and carbon monoxide emissions increase with very lean combustion, this is not a concern due to the wide availability of exhaust gas oxidation catalysts.

The NOx emissions decreased by roughly one order of magnitude going from ? = 1.1 to 1.5. At a given ?, NOx from pyrolysis gas fueling was higher than from natural gas. However, because the of the ability to operate the engine at higher air/fuel ratios on pyrolysis gas, the differences in NOx emissions between the two fuels can be negligible. Never-the-less, the lowest measured NOx value (4 g/kWh) at a load of 9 kW, is still an order of magnitude higher than proposed U.S. emissions standards for small generators. Further reductions in NOx emissions from SI engines will have to come from enhanced lean-burn performance and/or addition of exhaust after-treatment technologies. Alternatively, engines could run stoichiometrically with feedback control and a 3-way exhaust catalyst, as developed by the automotive industry.

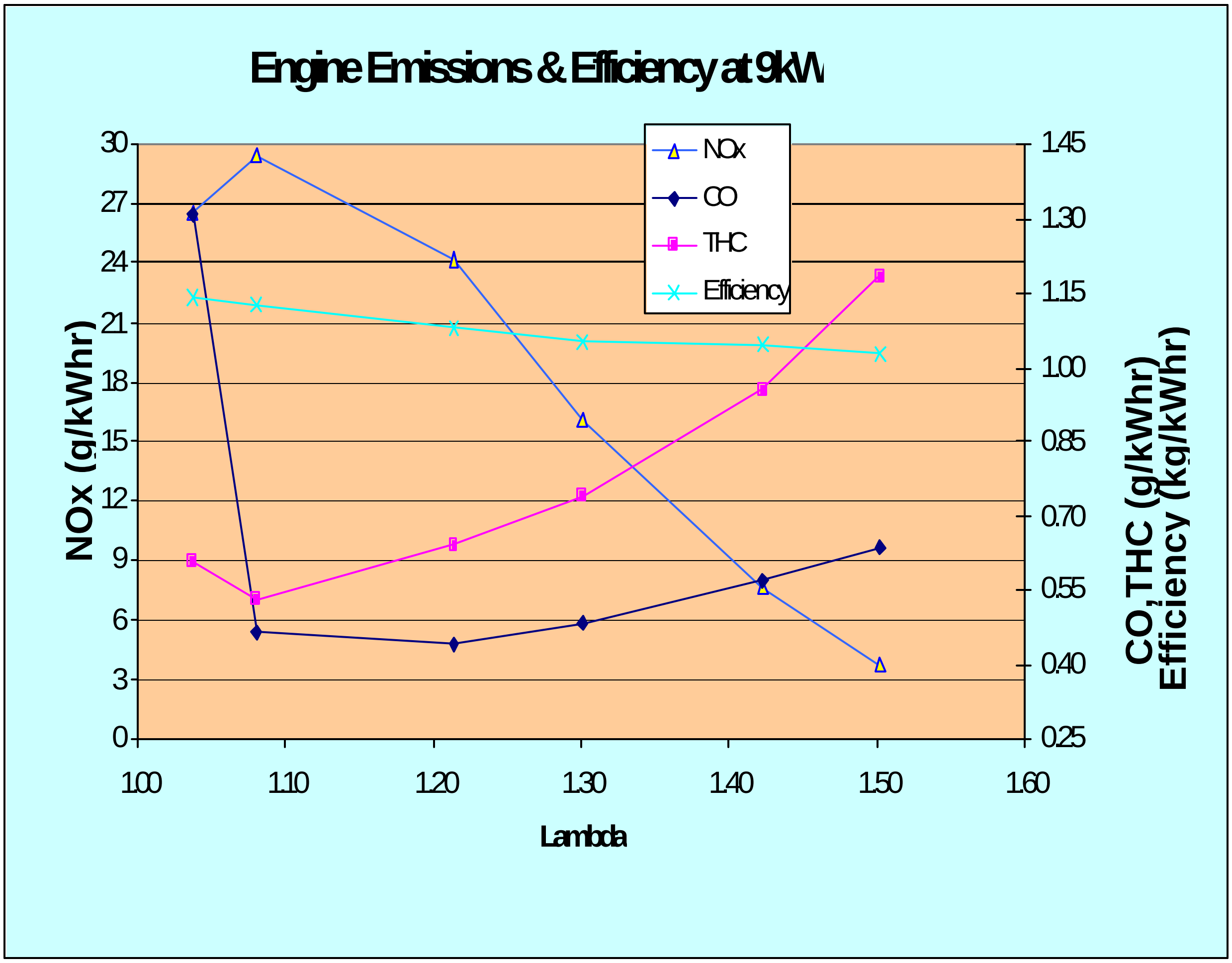

Figure 1. Engine emissions and genset fuel efficiency on pyrolysis gas, as a function of Lambda.

References

[1] S. Phillips, C. Baca-Overly , S. Deutch; C. Feik, J. Graham and M. Ratcliff. The Thermochemical Process Development Unit at N.R.E.L. Presented at the Fifth Biomass Conference of the Americas, Orlando, Florida, September 12-21, **2001**.

[2] Shashikantha, Parikh, P. P. Spark Ignition Producer Gas Engine and Dedicated Compressed Natural Gas Engine Technology Development and Experimental Performance Optimization. SAE 1999-01-3515, **1999**.

[3] Abdel-Rahman, A.A. "On the Emissions from Internal-Combustion Engines: a Review", Int. J. Energy Res., 22, pp. 483-513, **1998**.